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A critical examination of visual programming and generative design for the compliance checking of open plan office layouts against HSE guidelines post Covid-19.

BIM TUDublin
bim@tudublin.ie

Ronan Byrne

A critical examination of visual programming and generative design for the compliance checking of open plan office layouts against HSE guidelines post Covid-19.

Ronan Byrne[1] and Davitt Lamon[2]

School of Multidisciplinary Technologies

Technological University Dublin, Bolton Street, Dublin 1, Ireland

E-mail: [1]ronanbyrne9614@gmail.com [2]Davitt.Lamon@TUDublin.ie

Abstract ─ The purpose of this study is to explore the feasibility of Visual Programming (VP) and Generative Design (GD) in assisting employers review open plan office layouts against Ireland's HSE guidelines implemented in May 2020 in response to Covid-19. The pandemic has affected all areas of life with workplace standards requiring a complete overhaul. This study will attempt to ascertain compliance with natural ventilation and social distancing requirements through the completion of an experimental research study, utilising Computational Design (CD) tools. A GD study will be undertaken to provide the designer with numerous office layout design solutions to evaluate and evolve. The findings will be examined through a semi structured focus group study with industry professionals. All visual programming algorithms shall be repeatable and adaptable to be utilised on an individual project's unique situations. The author hopes this study will show that in theory, computational compliance checking, and computational design can be a viable workflow for designers.

Keywords ─ Generative Design, Visual Programming, Social Distancing

I INTRODUCTION

The current Covid-19 pandemic has caused widespread disruption to normal routine throughout the world. As businesses begin to reopen, guidelines to ensure a safe transition back into the workplace have been published by countries' health authorities worldwide. While the guidance can vary depending on the specific region, the importance of natural ventilation and social distancing are two points that continue to be stated in reports. In May 2020, the HSE in Ireland published a 'return to the workplace' report reiterating the importance of these measures [1]. This results in many workplaces having to carry out a complete review their current seating arrangement.

As part of their return to work strategy, multinational coworking company 'WeWork' suggest using the measuring tape and masking tape approach to ascertain if adjacent desks encroach within a 2 metre radii of each other [2]. The author undertook an early experiment to assess this method. It took approximately 45 seconds to measure and mark a 2 metre zone around a single desk. WeWork has five office locations in Dublin alone, with its Charlemont Exchange office containing 2,400 desks [3]. Extrapolating the authors initial study across that specific WeWork office, it would take approximately 30 continual hours to assess every single desk. That is not including time spent travelling between desks or floors and assumes the employee maintains the same speed throughout.

While a more substantial study should be carried out on this method, the early findings did provoke the question for the author of whether this task could be carried out in a more efficient and accurate manner. There has been a copious amount of research carried out on the use of Project Information Models (PIM) and Visual Programming (VP) tools as a means of compliance checking in recent years [4]. Could the same algorithmic approach adopted in these studies be utilised as a template for this study? Is a Generative Design (GD) study appropriate for this workflow? To answer these questions, the author has divided the paper into six primary sections.

Section 1 of this paper outlines the problem facing the construction industry, discussing suggested resolutions and possible solutions. Section 2 of this paper will critically review the principle of visual programming for compliance checking through a literature study. The author will also critically review the theory of generative design, and its current uses by architectural designers within the construction industry. All information has been established from conference proceedings, past research completed and specific vendor material.

Section 3 of this paper will outline the steps taken by the author as part of an experimental research study. The study explores the use of visual programming and generative design tools to assess compliance with building regulations and generate multiple data assisted design options. These design options can be used to facilitate designers when rationalising office workspaces in line with Covid-19 guidelines. These algorithms are repeatable and adaptable to suit an individual project's needs.

Section 4 of this paper will discuss the analyses of the workflow outlined in Section 3. The author completed a semi structured focus group study with industry professionals to assess the viability of the workflow, discussing the potential benefits and the possible challenges implementing it. A follow up survey was completed by all participants providing the author with statistical data assessing the workflows viability. Sections 5 and 6 conclude the findings and discuss areas of future work for this study.

II Literature review

a) Visual Programming for Compliance Checking

Compliance checking is a complex task, with many challenges experienced in the current manual checking system [5]. There is a consensus among researchers that an ambiguity around building regulations and codes due to personal interpretation and experiences can impact compliance checking [4]. Automated rule checking of BIM models is seen as a potential solution to that problem [6]. Solihin and Eastman note that compliance checking of Building Information Modelling (BIM) models is a broad topic and can cover as many as seven different fields including building regulations, client requirements, handover completeness and warranty checks, among others [6].

There are several systems in place already for compliance checking of BIM models against building regulations and codes [7]. In Singapore, the CORENET e-PlanCheck system is used to assess compliance of BIM models, specifically in the areas of fire safety, building control and barrier free access [7]. The system was developed and managed by and independent body called FORNAX [5]. Altering of the compliance checking process could not be completed by individual users, for this reason the system failed initially [5].

Another system used is the SMARTCodes system in the United States, developed by the International Code Council (ICC) [7]. The system divides components into four categories; Requirement, Applicability, Section and Exception [7]. A flaw in this system means that expert knowledge cannot be calculated as it is not a definitive standard. Guidelines that require interpretation and sign off from an individual, such as a fire officer are not included in this compliance check system [7].

A continual limitation of systems such as the CORNET e-PlanCheck system or the SMARTCodes system are the inability to be adapted. These systems also require the use of a BIM tool separate to the design of the model. The model must be exported to either XML or IFC format [4]. This may lead to human errors when reviewing a report that is not directly linked back to the designers model [4]. Recent studies have explored VP tools that can provide designers with a more complete way of assessing compliance through their PIM. VP tools that would provide the designer with the ability to adapt or change the system to suit the individual project's needs, or changes to building regulations. These VP tools would work with the designer's model directly.

Visual programming is a form of computational design and is unique from traditional text based programming [8]. A VP algorithm is typically referred to as a 'graph' and primarily does not involve code writing. The algorithm is graphically collated through 'nodes' [9]. These nodes contain 'inputs' and 'outputs', and are connected through 'wires' forming a network of nodes to show a graphic representation of the required steps to achieve an end goal [9]. One of the more commonly used VP tools by architectural designers is Dynamo. Dynamo is an "*open source programming environment*" [4] with an application included in all Revit versions since 2017 [10]. The tool allows designers to "*create and explore parametric conceptual designs and automate tasks*" [11].

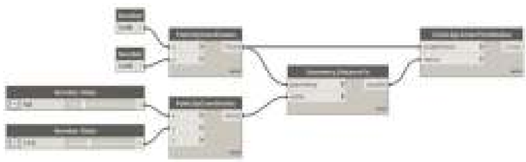

Figure 1 - An example of a VP graph created in scripting tool Dynamo [12].

Recent academic papers published have examined the use of VP tools, such as Dynamo, in completing several of the previously stated compliance checks. In 2017, Reinhardt and Matthews examined use of automated BIM, specifically VP, for compliance checking from a holistic standpoint [5]. In 2018, Harrell and

Matthews explored the automation of BIM for compliance checking with a specific focus on compliance with fire regulations [4]. In 2019, Colley scrutinised the use of VP tools for the creation, verification and validation of project information with the PIM [13]. The three papers referenced above are a small sample of the research completed in this field. Little research has been carried out on VP tools being utilised as a compliance check of Covid-19 guidelines given the current nature of the pandemic.

There are some critical steps required if this workflow is to succeed. Greenwood et al. state that consideration must be given to model authoring [14]. These algorithms rely heavily on accurate and complete PIMs. A failure by the designer to construct the PIM adequately would result in the graph failing to complete the task. Also, VP graph authors must remain up to date with changes to regulations and codes [14]. A graph should be continually evolving and updating in line with changes to the building regulations. A tracker for managing the graphs is recommended to assist with this.

b) Generative Design

"We believe that there may be good design solutions that are never found because they are laborious to discover, and labour is at a premium" – Anthony Hauck, former Autodesk Director of Product Strategy for Generative Design [15].

As stated by Hauck, the design process can be a laborious and time consuming workflow [15]. To achieve better performing and more sustainable architecture, designers have turned to Computational Design (CD) tools in recent years [16]. CD does not refer to a single workflow or design algorithm, more so a workflow that involves setting out rules and requirements to find an particular outcome [12]. GD can be categorised as a CD workflow. GD provides designers with unique and high performing design solutions using metaheuristic algorithms [17]. The GD workflow can be categorised under the three main headings below.

- Generate – Multiple design options are created by the computer using a search algorithm and specific parameters created by the user. This process has recently been referred to as 'co-design' – the collaboration between computer and human [18].
- Evaluate – All designs created are analysed to assess how well they complied with the designer's requirements.
- Evolve – The various design options are ranked based on their alignment with the designers' requirements and evolve the study further based on these rankings [19].

Figure 2 - Diagram demonstrating the generative design workflow [19].

In theory, GD addresses possible human limitations with the semi-autonomous design of a space completed by the computer [20]. This design is then reported back to the designer for further analysis and evaluation of the results [21]. Prior to completing this task, the geometric model requires further input in two fields [18]. The operator must outline definitively which parameters are to be evaluated and ranked as part of the study [18]. This provides the computer with concrete metrics to score designs, given the lack of the machines design intuition [21]. Secondly, an algorithm must be created and linked to a search algorithm in order to manipulate input parameters, receive feedback from the study results and list the results of all design options, providing the designer with the highest performing outcomes [21].

Figure 3 - Outcome of GD study completed as part of 'Project Discover' [21].

There are a number of search algorithms that can perform this task, however one in particular is seen as the most promising amongst researchers [21]. Multi-objective genetic algorithms (MOGA) is a search algorithm that generates multiple 'generations' of designs, thus providing designers with a more complete study [21]. These 'generation' groups can be composed using one of two systems depending on the designer's requirements [21]. Each group begins the same way. A selection of initial designs completes the 'first generation', which will be further developed as part of an ‘elitism’ study or a ‘cross breeding’ study. An elitism study produces subsequent designs of the highest performing design results. Cross breeding combines the parameters of two high performing results randomly, creating one new design in the process [18].

The main advantage for this type of search algorithm system is the user is not required to predetermine the parameters of greater importance. A design’s ranking is determined by the relative performance of all parameters combined over another’s results [21]. A design with multiple parameters scoring higher overall will be weighted higher, as opposed to individual parameters. This system provides users with more definitive results. This process is referred to as ‘dominance’ [21].

In their paper published at the CitA BIM Gathering 2019, Lamon and Behan note a severe limitation of this design workflow is that as a numeric value is required for all input and output parameters, architectural goals such as the design’s aesthetics or novelty are not considered [18]. Gerfen states that a solution to this limitation would be to subdivide the architectural performance requirement into three fields. Architectural goals such as aesthetics or novelty would be listed under the third heading of the below fields.

1. Quantifiable metrics using existing tools
2. Quantifiable metrics in theory but not using current tools
3. Non-quantifiable metrics [15].

Another limitation of this workflow is time. Currently, it takes roughly one minute per design to perform the study [21]. While it is still more efficient than human design, this rate of speed does reduce the extent of exploration designers are willing to tolerate. A possible solution to this as stated by Nagy et al. would be to subdivide the work across multiple computers on the same network. This way, studies can run simultaneously without dramatically impacting a designer’s time [21].

To further highlight the growing importance of the MOGA search algorithm in GD, in the past year, Autodesk have included a version of this search algorithm as part of the Generative Design for Revit 2021 release [18]. This search algorithm was later used by the author as part of an experimental research study, as described in Section 3 of this paper.

Once the data has been generated, it must be analysed to assess the best performing result. As part of the Generative Design for Revit 2021 release, two data analysis tools are provided. They are ‘Inheritance Analysis’ and Metric Space Analysis’ [18]. Both systems plot the same data, but represent said data using different aesthetic formats to best suit the user [21]. Inheritance analysis provides users with a ‘parallel coordinates chart’ [22]. The columns in these charts represent the pre-set performance criteria. A single black thin line entering from the left indicates a design carried into the next generation, while two multi-coloured lines indicate cross breeding. This analysis system is best used to indicate potential blind spots in the design [21].

The metric space analysis tool provides users with a ‘scatter plot’ [22]. The user can set the X and Y axis to one of the predetermined performance criteria, and the user can further highlight higher performing results by changings the size and colour of the plotted data. This allows us to spot trade-offs between different designs [18]. These data analysis tools were later used by the author, as described further in Section 3 of this paper.

III EXPERIMENTAL RESEARCH

The experimental research study was divided into four stages by the author. These stages are:

1. The design of a geometric Project Information Model (PIM) to be utilised as the basis for this study.
2. The creation of a visual programming algorithm to assess the PIM’s compliance with natural ventilation requirements for open plan offices in Ireland.
3. The creation of a visual programming algorithm to assess the PIM’s compliance with social distancing requirements published by the HSE in May 2020.
4. The creation of a visual programming algorithm to complete a space planning generative design study to assess the best performing seating arrangements shown in the PIM.

a) Stage 01 – Creation of Geometric PIM

The first stage of the workflow was to create a geometric Project Information Model to be utilised throughout this study. The author used Revit 2021 to create this file. The PIM consisted of a single floor of a medium sized open plan office workspace, several smaller meeting rooms, and a circulation zone in between. Each room had either a fixed window, a side hung window or a curtain walling screen with several opening sections. A typical seating layout was shown in each room with a total number of 136 seats desks within the model.

For this study, the PIM contained several rooms non complaint with the current natural ventilation guidelines and a desk layout with adjacent seats encroaching within a 2m radii of each other. The purpose of this was to allow the author highlight and propose solutions to non-conforming elements.

Several shared parameters not in the original Revit template were added to relevant categories and families. A 'Room Number' parameter was added to all curtain walls, floors, furniture, rooms, and windows. A formula was also added to all window families to calculate the free air of any opening sections within the family. This 'Opening Section Area' parameter is critical to the study as this data is essential to Stage 02 of the experimental research study. At this point the model was purged of unused elements to avoid any unnecessary noise interfering with the study.

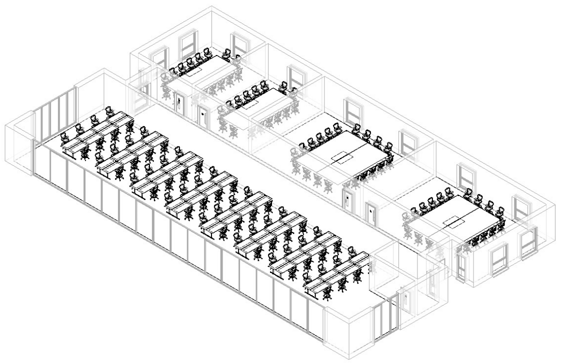

Figure 4 - Image of PIM created as part of experimental research study.

b) Stage 02 – Assessing Compliance with Natural Ventilation Requirements

A key factor in the safe return to the workplace is being able to provide employees with sufficient natural ventilation. The HSE state that adequate ventilation should circulate throughout the office workspace [1]. No further information was provided to determine what could be considered "adequate", for this reason the author chose compliance with Table 4 of TGD Part F 2019. This states occupiable rooms in non-dwellings should have a provision of window opening sections for a minimum of 1/20th of the room's total floor area [23].

To complete a compliance check of this requirement, the author selected VP tool Dynamo. The out of the box Dynamo packages were primarily used for this stage, with Clockwork for Dynamo 2.x and Rhynamo packages also installed. The Dynamo graph can be organised into the five primary tasks below:

1. Firstly, all graphic overrides of floors within the active view of the PIM are reset. The output of this study will be the surface pattern of the floor being overridden and coloured red. This step eliminates the risk of any previous studies' results interfering with the current study. The 'OverrideGraphicSettings.ByProperties' and Element.OverrideInView' nodes were critical to this step.
2. Using the 'All Elements of Category' node, all windows and curtain wall panels are identified. The 'Element.GetParamaterValueByName' node was used to extract data within the 'Opening Section Area' parameter created in Stage 01. This identifies the amount of free air provided through each glazed element. This list was sorted by room number.
3. Extract all rooms within the model and filter out any non-habitable rooms as they not subjected to the same natural ventilation requirements. Find the area of these rooms and multiply it by 0.05 using the 'Multiply' node. This provides the user with the amount of free air required per room, as stated in TGD Part F 2019. Again, this list was sorted by room number.
4. Combine the 'Opening Section Area' value of any windows or curtain wall panels hosted in the same room and compare the final room free air provided value against the free air required value. This was completed using the 'Less Than' and 'List.FilterByBoolMask' nodes, among others.
5. Lastly, list all rooms that do not meet the free air requirement. A note stating the room is non-conforming with TGD Part F 2019 is added to the 'Comments' parameter through a 'Code Block' and the 'Element.SetParameterValueByName' The floor finish surface pattern graphic within each room is overridden, highlighting in red non-compliant rooms.

The list of nodes named throughout the above steps is non exhaustive and does not represent all nodes required to complete the check. The output of this study is view specific and the algorithm is adoptable to suit individual project's needs. The below image represents the output of this Dynamo graph when used to assess compliance within the geometric PIM created in Stage 01 of this study.

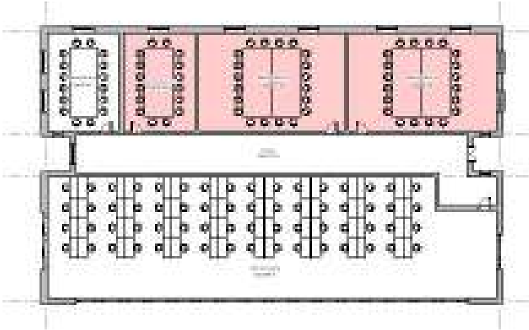

Figure 5 - A typical floor plan highlighting rooms non-compliant with TGD Part F 2019.

c) Stage 03 – Assessing Compliance with Social Distancing Requirements

The next stage of the experimental research study was to assess the current layout's compliance with the social distancing requirements introduced by the HSE in May 2020. This states that persons must maintain a two metre distance minimum from another when indoors [1]. As in Stage 02, the author selected Autodesk's Dynamo VP plugin with Revit 2021 to create an algorithm for this compliance check. As in Stage 02, the out of the box Dynamo packages, Clockwork for Dynamo 2.x and Rhynamo packages were used in the creation of this graph. This graph can be organised into the four sections described below:

1. Using the 'Document.ActiveView' node, the first step was to get the level of the active view within the model and to extract all rooms located on that level. This meant that only the view in question was being examined. This can be ignored if the user chooses to complete a study of the entire building.
2. Secondly, using the 'Family Types' and 'All Elements of Family Type' nodes, the specific Revit family the study is based on is selected. In this case the family was an office chair. The chair families are grouped based on the room they are contained in on the selected level. The 'List.GroupByKey' node was critical to this step.
3. Once that is completed, next the author grouped the seats based on their proximity to each other and set a minimum distance required between them. At this step, the author filtered the overall list of office chairs based on the minimum distance requirement and was left with two lists. A list of occupiable seats and one of unoccupiable seats. 'Code Blocks', 'List.FirstItem' and 'List.GetItemAtIndex' nodes were used in the completion of this step.
4. The final step provides the user with two separate outputs. Firstly, a collection of nodes providing the user with critical information such as the total number of seats in the study, the total number of occupiable seats based on the set minimum distance and the percentage of occupiable seats. A formula was used in a 'Code Block' and a 'Watch' node to display this information. A graphic override of the Revit family is also included at this step, with occupiable seats turning green and non-occupiable seats turning red in the active view. This was completed using a 'Colour.ByARGB' node, allowing users to set the colour manually.

This graph is adaptable to suit an individual project's needs. As stated during Stage 01, the algorithm can either evaluate a particular room, level or the entire building depending on the specific requirements. Any distance can be inputted as the minimum separation and the output parameters can be added or removed as required. The colour of the overrides is adaptable to suit an individual's specific requirements. As mentioned at Stage 02, the list of nodes referenced is a small sample required to complete this stage.

While the graph performs the desired task, it could be further developed to enhance the user experience. One enhancement would be to link it to a seating chart created in Microsoft Excel by the office manager or employer. This could assign the number of employees whose day to day presence in the office is essential, informing the employer of any possible overcrowding issues.

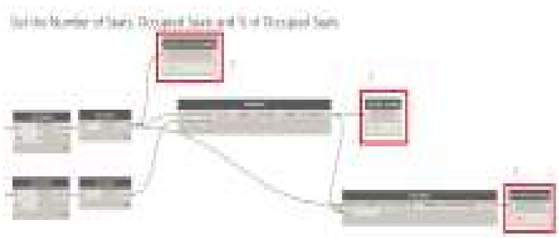

Figure 6 - Data outputs within the Dynamo script highlighting; 1) the number of seats within the model, 2) the number that are occupiable under social distancing requirements and 3) a percentage of total occupancy.

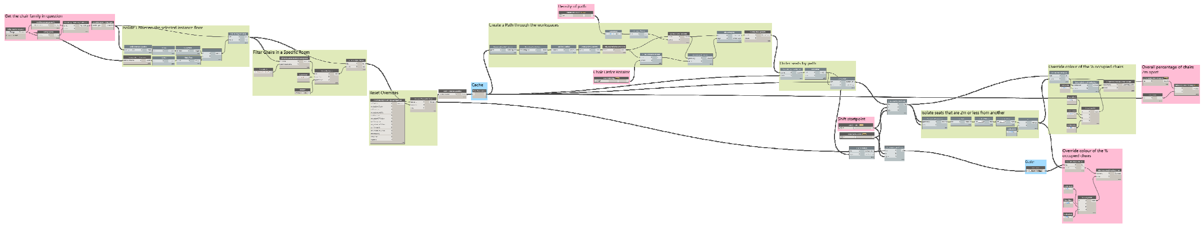

Figure 7 - Image illustrating the Dynamo script used as part of the Generative Design study set out in Stage 04.

a) Stage 04 – Utilising Generative Design tools to

The final stage of the experimental research study was to assess the best performing seating arrangements within the model using a GD search algorithm. In their 2020 paper, Lamon and Behan complete a GD study populating a desk layout into an empty office space [18]. This study attempted to find the best seating arrangement from an existing layout using distance between desks and occupancy percentage as the primary performance criteria.

As stated in Section 2 of this paper, to complete a GD study, there are three requirements. The first requirement is to have a geometric PIM. This provides the study with geometric constraints and boundaries. The geometric PIM created during Stage 01 of this study was used. Secondly, an algorithm is required to manipulate input parameters and list the results. As before, the out of the box Dynamo packages, Clockwork for Dynamo 2.x and Rhynamo packages were used in the creation of this graph. The GenerativeDesign version 1.3.1 package was also used. This algorithm can be divided into the following sections:

1. As in Stage 03, the first step is to select a specific Revit family using the 'Select Family Instance' node and select all instances of this family within a given level. This is automatically the level of the active view. At this point the author filtered the list further to all family instances within a specific room and reset any prior graphical overrides. This was also carried out in Stage 02 and it avoids any random noise from a previous study interfering with the current attempt.
2. Next, we insert a 'Data.Remember' node. This is critical to the GD study. The purpose of this node is to cache the results of a previous nodes output in the Dynamo file when saved [24]. What is normally temporary data converts to data still available to the user after the graph is closed.
3. The third step of this algorithm is to create a path through the workspace and to order chairs by this path. This was created by placing a circular bounding box around all selected families. Various points are placed along the circumference of the circle with lines connecting the different points. These lines for a grid. The density and rotation of the grid is determined using a 'Number Slider' nodes and is fluid during the GD study. As each chair family sits somewhere on that grid, the fluidity allows for several different layouts to be achieved. The GD search algorithm will use these nodes to find better or worse seating arrangements.
4. Two more 'Number Slider' nodes were inputted at the next stage. The purpose of the first is to change the shifting chair start point. This allows the GD search algorithm to explore unique layout options from every chair's perspective. The second is to drop every second chair, meaning a maximum of 50% occupancy is achieved. At this point chairs within two metre radii of an adjacent chair are also isolated. A 'Data.Gate' node is included to allow the user to generate the selected study from the GD interface to the Revit PIM.
5. The final step in this algorithm is to generate an output. As in Stage 03, the output consists of a graphical override of the occupiable chairs and data such as the percentage of occupancy. These outputs will be visible within the GD user interface. The graph is exported at this point.

The final step in this study is to import the algorithm into a MOGA search algorithm. As stated earlier in the report, this was recently included in Revit 2021 as was utilised by the author. A new study was created within the GD plugin and the graph was imported. The author chose a population size of 20 over 10 generations. This means that 20 different design solutions will be optimised and refined 10 times, providing a total of 200 design solutions. An example of the Revit 2021 Generative

Design user interface can be seen in figure 7. The dialog box contains a preview of each possible design solution. They are plotted on a scatter plot comparing all possible options. The design solutions were evaluated by the author using a metric space analysis tool within GD for Revit and a final design was selected. The selected design was automatically generated within the Revit model, overriding the seat graphics of the preferred layout.

Figure 8 - The user interface for a GD study within Revit 2021

IV EVALUATION

To assess the viability of the above workflows, the author hosted a qualitative semi structured focus group with eight industry professionals. Each participant's experience of BIM varied, with some working for many years as BIM coordinators and BIM managers, while others had little to no experience. This allowed the data collected to be an accurate reflection on the skill levels of the current industry workforce. The focus group forum gave opportunity for discussion and collaborative ways of thinking where sole interviews would not. This was the primary reason for selecting this method of evaluation.

The list of participants consisted of a senior construction manager, a BIM manager, three architects and three architectural technologists. Professionals from this sector were chosen due to the study's primary target audience of the architectural and interior design sector. All participants engaged throughout the presentation, providing meaningful insight and experience, while also contributing with unbiased views towards the proposed workflows discussed in Section 3 of this paper. All participants also completed a short follow up survey to answer questions not considered on the day of the presentation, and that arose because of reflection on the focus group responses.

Prior to participating in the focus group, all participants were made aware of their rights to withdraw from the study at any time, to refuse to answer any questions and of the right to anonymity. An informed consent form was signed by all participants in line with GDPR requirements. The presentation took roughly 45mins to complete with the format of the presentation set out as follows.

- An introduction to the research and project targets
- An overview of visual programming
- An overview of generative design
- A walkthrough of the three workflows discussed in Section 3.

Questions and analysis took place intermittently throughout as well as a discussion at the end of the presentation to discuss potential benefits, areas of concern and next steps. Prior to the presentation, half of the participants had little to no prior knowledge of visual programming or generative design. This was predicted, and for that reason the presentation began with a brief overview of visual programming and generative design.

Several participants commented on the reliability of a script being a big advantage over current methods of compliance checking. The reduction in human error in tandem with an increase in time saved was generally viewed as a sufficient reason for adopting this workflow. On average, participants anticipate visual programming could see as much as a 70% reduction in time spent checking drawings for compliance with buildings regulations. While all participants stated they would feel confident working with the tools presented, it should be limited to simple tasks. The full Dynamo graph could be considered *"overwhelming"* to someone unfamiliar. The author noted that Dynamo Player may be a more appropriate tool for some users as it does not require the same understanding of Dynamo.

Next discussed was the implementation of the generative design workflow into architectural design on a regular basis. The consensus amongst participants was they would likely implement the workflow as it allowed multiple designs to be considered with a steep reduction in time spent doing so. Several participants observed the potential expansion of generative design away from commercial office layouts into the residential sector, with the feasibility stage of a project been best suited.

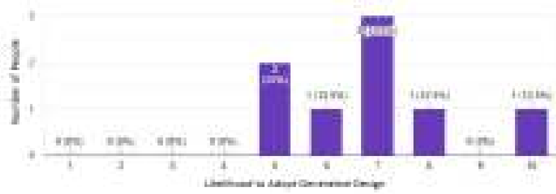

Figure 9 - Chart representing the number of people willing to work with GD, an average figure of 7.31.

Consistent feedback from the participants notes the possible disadvantage of too much generative design. One participant stated, *"these parametric workflows when applied for several areas could limit design input or creative time dedicated for projects, although making the overall project more efficient and correct"*. The concern about whether the buildings overall aesthetic and function is affected by generative design is also shared by another participant, specifically regarding the amount of possible design solutions; *"while it allows multiple options to be considered, the disadvantage is if you don't put a cap on an upper limit for options, they process could get out of control"*.

Lastly, several areas for improvement and advancement were discussed. Suggestions varied, for instance one participant noted a desire to see the second workflow, visual programming for the compliance check of social distancing requirements, incorporate data on the different divisions within the company inputted into the seat family. This would keep teams seated together in the same group, while still socially distant. Another noted how a check for the quality of natural light at each seat could be incorporated into the input parameters of the generative design study in workflow three. The skillset required to complete this step is outside the authors knowledge. A final suggestion would be to incorporate the overall window schedule creation into the first workflow. It was stated most tier 1 contractors in Ireland require window schedules in Excel to cross check ventilation calculations. Exporting the results of workflow 01 would make this contractor requirement redundant, as it would provide them with hard numerical data highlighting compliance.

V CONCLUSION

The purpose of this research study was to explore the possible uses of visual programming and generative design tools for compliance checking of open plan offices against Covid-19 measures implemented in Ireland. It was demonstrated through an experimental research study that several workflows could be adopted to assist employers ensure their workplace environment is complaint with recently published standards.

The success of these workflows was later reaffirmed through a semi structured focus group. 73% of participants stated their desire to work with generative design in the future, while 69% stated their desire to work with visual programming in the future. Prior to this survey been completed, only 50% of the participants had admitted to having any knowledge of either design tool. The uptake of circa 20% for both tools shows the benefits industry professionals see these tools bringing to their current practices. Not that these workflows are without limitations.

As discussed during the proposed workflow's evaluation, the openness of the software allows users to generate unlimited versions and design options. While this is marketed as a benefit by software vendors [17], many participants noted the possibilities to get lost in the software, and the process spiralling out of control. It was suggested that it could become more of a hindrance than anything else. The author would note that greater training is required to ensure the benefits are fully experienced.

In Section 1 of this paper, the author discussed an early experimental study completed, on the back of guidance published by coworking company 'WeWork'. A masking tape approach was suggested to assess whether your colleague was seated within 2m of you. The author concluded it would take approximately two days to check one of their many offices. The "*work smarter, not harder*" cliché comes to mind here. The benefits experienced with the workflows proposed in Section 3 primarily include time saved and accuracy. The author believes this paper demonstrates 'WeWork's task could be greatly reduced by adopting the computation design methods outlined.

Lastly, there is a fear amongst a small section of the industry that the automation of tasks could be the beginning of the end for architecture as we know it. In 2019, leading architectural magazine 'Dezeen' published an article quoting designer Sebastian Errazuriz saying "*90 percent of architects will lose their job to algorithms*" [25]. While it is a more extreme view, it does highlight how computational design is viewed by some professionals. Continual webinars and demonstrations are necessary throughout the industry to reassure architectural designers of the merits computational designing can bring. To remind users that these programmes are still tools no different to proprietary drawing software.

The next step for computational design in architecture is to expand the uses of these software into untouched areas of design. As noted at the beginning, research into BIM for compliance checking of ventilation and social distancing requirements was limited. Some work had been considered for other building regulations though. A possible study into the area of BCAR and BIM is a topic the author would have a great interest in, given the ever-growing importance it is having in the Irish construction industry.

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